

GENESIS OF THE VAN ALLEN RADIATION BELTS

ORIGINS OF MAGNETOSPHERIC PHYSICS

James A. Van Allen, *University of Iowa*

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It is difficult and perhaps inappropriate to write a conventional review about a book that is an autobiographical memoir as well as a technical treatise; hence my title and approach, which will include some relevant comments about the book as well as on the events. Two book reviews^{1,2} by well-known scientists external to the University of Iowa have already appeared; this review is by one who was quasi-trapped in Iowa in the wake of the discovery of the Van Allen radiation belts and who had the opportunity of experiencing the excitement of the time and place.

Often the view of the general public about a discovery does little credit to the effort behind it—it is as if someone pressed a button accidentally and, lo and behold, there is a discovery! Such a superficial perception grossly underrates the achievement, which is quite clearly a culmination of serious systematic studies that span many months or several years. Van Allen's book brings into focus the spirit of continuity and its evolution. One can feel the spirit of adventure and recognize the ingenuity that is part and parcel of scientific exploration. Furthermore, the autobiographical component brings into perspective the personality of the man behind the project. It is good to see an active scientist write such an account; it certainly fills a void in the discipline of the history of science. Only the person connected with the discovery, or perhaps a colleague who has closely participated in the project for a long period, can feel the pulse and transmit effectively the excitement of the work. Such an account also tends to humanize the erroneous image of an "isolated" scientist engrossed in his research and not involved in the world.

The book traces the origins of magnetospheric physics back to studies of cosmic rays against the backdrop of solar-terrestrial relations. The subject of time variations of cosmic rays may be considered 50 years old, beginning with the investigations of Scott E. Forbush of the Department of Terrestrial Magnetism (DTM) in Washington, D.C., who is cited by Van Allen in the following fashion: "During this period (1939-40), I had acquired an interest in cosmic ray research from Scott Forbush and others at DTM." The discovery of the

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Scott E. Forbush and James A. Van Allen. (Photo courtesy of Carnegie Institution of Washington, D.C.)

radiation belts in turn has spawned a massive and flourishing science called heliospheric physics; consequently, we now talk about solar-planetary relationships. It is good to see a book that bridges the two areas, one old, namely cosmic rays, and the other new, namely heliospheric physics, and in addition provides an intimate and warm account of the circumstances and details of the birth of a new era in physics.

The spirit of the times, the post-World War II development of high-performance rockets in the United States and the Soviet Union, and the spirited competition between the two nations culminating in the launching of the first man-made satellites from both countries, etc., are vividly brought out in the book. The beginnings of Van Allen's interest in space physics can be traced back to January 1946, when V-2 rockets were offered to interested scientists as vehicles for carrying instruments to previously inaccessible altitudes. As a staff member at APL and with the support of its director, Merle A. Tuve, he organized a high-altitude research group of kindred spirits (see the companion article on High Altitude Research at APL in the 1940s in this issue).

The remarks on the period 1946-57, although brief, are nonetheless revealing, in that it was indeed the incubation period before the leap into the space age. The essential homework during that interval really formed the basis of all the successes that followed. Van Allen's survey and the step-by-step unfolding of the nature and complexity of the radiation belts, with due recognition and appropriate credits to the observations from the satellites and spacecraft of the Soviet Union,

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provide rewarding reading. Furthermore, it is refreshing to read a candid comment such as: "But much of the pioneering work, both American and Soviet, was deficient in two important respects (a) the failure conclusively to identify the species of particles responsible for the responses of the various detectors...." Such open admissions of one's limitations are rare indeed!

The professional pride, which is in a sense an expression of the personal sentiment of a job effectively executed, comes through on page 91: "During 1958, the Iowa satellite research group consisted principally of three very talented and assiduous graduate students (Ludwig, McIlwain and Kasper), an able tough-minded young undergraduate student (Frank), a recent PhD Assistant Professor (Ray) and myself ... 3 skilled instrument makers, J. George Sentinella, Edmund Freund, Robert Markee...." This is the best recipe for success the book provides and gives richly deserved recognition for dedication and teamwork, which are always the vital components to any successful enterprise. It is so good to see this in print! After all, as Sir C. V. Raman, Nobel prize-winning discoverer of the Raman effect (the blue of the sky, in popular parlance) used to say about scientific discovery "90% is perspiration, 10% is inspiration, or should I say, 95% and 5%?"

In comparing the past with the present (1983), Van Allen legitimately laments the current dreadful decade between the start of a project and its consummation. He calls for some thought of reducing the considerable administrative red tape that has become typical of present-day operations. This is a matter that, if attended to, would result in increased professional productivity. In conclusion, the book provides delightful reading with a variety that ranges from logbooks in the field to formal statements for a scientific meeting, from a feeling of frustration at almost missing an opportunity to elation at achievement, and from budget proposal to finished product. The book is strongly recommended for providing the opportunity to the readers to participate mentally in a scientific discovery that unfolds like a detective story.

It is relevant to conclude this article with some reminiscences about my experiences at the University of Iowa. The Department of Physics was still housed in the Physics Building (built in 1909), with names of famous physicists of the past engraved on the outside walls near the top of the building. Once, it appears, there was a plan to air condition the entire building

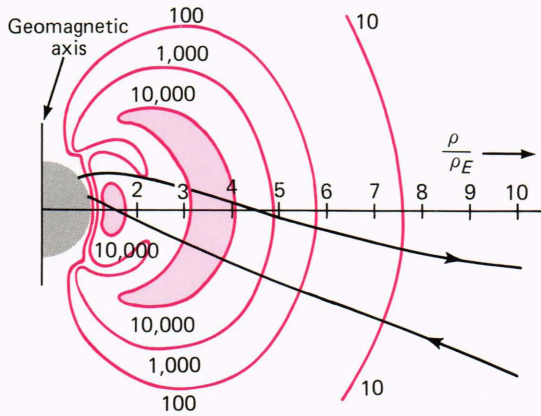
so the windows were shut tight and not designed to be opened. But something happened and there was no general air conditioning. This was a small matter and no one seemed to take any notice of it. However, if you had equipment in your room, you could get the room air conditioned. This was a case of catering to the comfort of machine over man.

In 1960 the basement was still the hub of all laboratory activity, and space hardware was being built and tested there. The department make-up reflected a continuation of the spirit of the International Geophysical Year (IGY) with graduate students and researchers from all parts of the world. The IGY was a symbol of world-wide collaboration for a common cause—pursuit of scientific knowledge.

In the early days, the pip-counting crew, reading off the satellite-borne detector counting rates from paper charts, was a sight. The number of undergraduates from across the entire University (not necessarily doing science, much less physics), supporting themselves and their education by being involved in this gainful occupation, were many. Wiring of electronic circuits by women was part of the scene in the early sixties. This was the nearest equivalent to the modern version of the "thread and wax" atmosphere of a laboratory of an earlier generation.

Two things stand out in my mind—the access to Van Allen and the lunches at the Jefferson Hotel. No matter how busy Van Allen was, it was always possible for a student or research associate to walk into his office and discuss the research project on hand. In addition, lunch at the Jefferson Hotel was an everyday occasion, when one could join Van Allen and other faculty members such as Max Dresden and Ernie Ray. The gatherings provided a forum for discussion of the topics of the day, almost always physics-related and often project-related, but interspersed with other topics from politics to philosophy. The presence of Max Dresden, a very versatile theoretical physicist, added variety and color to the discussions.

A distinct and new development of the times was the concept of the magnetospheric B-L coordinates introduced by Carl McIlwain, enabling one to organize the radiation belt data in a more meaningful and convenient fashion. The coordinates B (scalar magnetic field) and L (the radius of the equivalent shell [in units of earth radius] on which the charged particle was constrained to move) became the natural coordinates for the magnetosphere.



Intensity structure of the trapped radiation around the earth. The diagram is a geomagnetic-meridian section of a three-dimensional figure of revolution around the geomagnetic axis. Contours of constant intensity are labeled with numbers 10, 100, 1,000, and 10,000 which are the true counting rates of an Anton 302 Geiger tube carried by Explorer IV and Pioneer III. The linear scale of the diagram is relative to the radius of the earth, 6371 kilometers. The outbound and inbound legs of the trajectory of Pioneer III are shown by the slanting undulating lines. The intensity structure is a function of detector characteristics. (From *J. Geophys. Res.* **64**, 1684 (1959).)

The presence of Scott Forbush, grand old man of cosmic rays, added to the stature of the department. His somewhat Mark-Twainish appearance, with a perpetual unlit cigarette on his lips, illuminated the scene. Three or four of us were associated with him in research. His keen insight and meticulous attention to statistics cannot be overstressed, and his delightful sense of humor found itself in occasional expressions, such as, "I am glad they did not call it Forbush slump or Forbush decline, but only Forbush decrease."

The early sixties (in the wake of the discovery of the radiation belts) is the approximate cutoff date for Van Allen's account, for two reasons. I quote: "First, the principal elements of magnetospheric physics were moderately well recognized by then. Second, relevant

investigations proliferated at such a rapid pace thereafter that I felt unable to do them justice within the time that I had available for this work." The next generation of Iowa physicists was starting to appear during 1960-65; Brian J. O'Brien (a faculty member) deserves mention—he was responsible for the first satellite built entirely at the University of Iowa, Injun 1. Among students of that era, in addition to those mentioned by Van Allen, one recalls T. P. Armstrong, D. A. Gurnett, S. M. Krimigis, and S. Shawhan, who continue to contribute to solar-terrestrial and solar-planetary relations.

The exploration that began with balloons, rockoons, and Explorer I has continued and culminated in the Pioneers and Voyagers that continue to provide us data from in situ measurements far out in the heliosphere, establishing new spacecraft records in distance and heliolatitude. It is a matter of distinction that Van Allen continues to be one of the scientists at the new frontier.

I would like to conclude on a note about cosmic rays. Cosmic ray physicists of earlier (ship-sailing) days are quite familiar with the arduous task of executing latitude surveys with a shipborne detector. Even a single latitude survey from a few degrees north, passing the geomagnetic equator, and down to a few degrees south and back would be considered an accomplishment, and it certainly was! However, when we could use the Explorer VII data and accumulate two thousand latitude surveys within a single diagram, the feelings of satisfaction and elation that the three authors (Van Allen, Wei Ching Lin, and I) felt are something to cherish.

The chain reaction that started at Iowa has continued and contributed to our enhanced understanding of the magnetosphere—or rather the heliosphere.

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